BIOMARKERS IN LAVA CAVES: AN ANALOG FOR THE SEARCH FOR LIFE ON MARS. M. N. Spilde[1], J. J. Medley[2], D. E. Northup[2], and P. J. Boston[3]. [1]Institute of Meteoritics, MSC03-2050, 1 University of New Mexico, Albuquerque, NM 87131, mspilde@unm.edu; [2]Dept. of Biology, MSC03-2020, 1 University of New Mexico, Albuquerque, NM 87131; [3]NASA Ames Research Center, Moffett Field, CA 94035.

Introduction: In 2007, the first pit craters were observed on the surface of Mars. These are places where the roof of a lava tube has partially collapsed, creating a "skylight." Over 100 pit craters and possible cave entrances have been spotted by Mars orbiting imagers (e.g. Mars Reconnaissance Orbiter) [1], evidence of potential lava caves under the surface of Mars. Conditions in caves are typically radically different and more benign than surface conditions. As prime microbial real estate on Mars, lava caves would offer an environment that provides: 1) protection from ionizing and ultraviolet radiation, 2) insulation from thermal oscillations, 3) likely availability of water, and 4) access to chemolithotrophic energy sources such as Fe, Mn, and S. On Earth, microorganisms, larger organisms and even humans have gained protection by using caves as habitat.

For more than a decade, we have investigated the idea that the subsurface of Mars is the most likely place to find life or its traces. We have conducted extensive geomicrobiological, mineralogical, and geological fieldwork in a variety of lava caves in tropical to arid conditions. Many microbial forms are unique to the subsurface and have developed into countless novel strains [2]. Nearly all the caves that we have sampled show some evidence of microbial activity in the form of biofilms, slime, or microbially induced or precipitated minerals [3].

Biomarkers: A large part of our work has involved examination of cave mineral samples using scanning electron microscopy (SEM) coupled with DNA analysis. Culturing of organisms on various recipes of metal-containing nutrient is also used to discern the preferred diet and viability of the microbial community [2]. While morphology alone can be ambiguous, the presence of bioavailable metals and products can provide stronger evidence of biological activity. Oxidizable metals such as Fe, Mn, Cu, and S are utilized by the microbial community and the process will generally leave evidence in place, for example iron or manganese oxides on cave walls and ceilings.

Biofilms. A colorful and diverse array of biofilms with colors from white to pink to gold and shades in between have been studied in lava caves from the western U.S., Hawaii, and the Azores [3]. Oxide, carbonate and sulfate minerals are intimately associated with the biofilms, the minerals resulting from induced precipitation or as respiratory by-products. This close association of "microbes masquerading as minerals" provides key evidence of microbial activity.

Mn-oxides. Coatings and crusts of biogenic manganese oxide can be present on cave walls or associated biofilms. The material occurs as amorphous MnOOH, poorly ordered birnessite [4] and todorokite.

Fe-oxides. Iron is typically abundant in the host basaltic lava. Although free Fe^{2+} resulting from chemical weathering or other alteration of the lava is easily oxidized at even low pO_2 values, in the host rock it is stable and thus provides potential energy source for microorganisms. The microbial community can release organic acids that will break down bedrock, liberating Fe and other elements that can be used by metal oxidizers in the community [5].

Cu and V minerals. Precipitated Cu minerals (poorly crystalline chrysocolla) have been found in close association with microbial communities in several lava caves in Hawaii and New Mexico [3]. Likewise bright yellow, filamentous V-oxides have been discovered in microbial colonies on the walls of a cold lava cave, high on Mona Loa in Hawaii.

Sulfates and carbonates. Both calcite and gypsum may be present as moonmilk, a coagulation of disordered micro- to nano-sized individual crystals, plastic in nature, and containing up to 80% water as a paste (or as a crust when dry). Moonmilk may be of biogenic origin, chemogenic or of mixed origin [6].

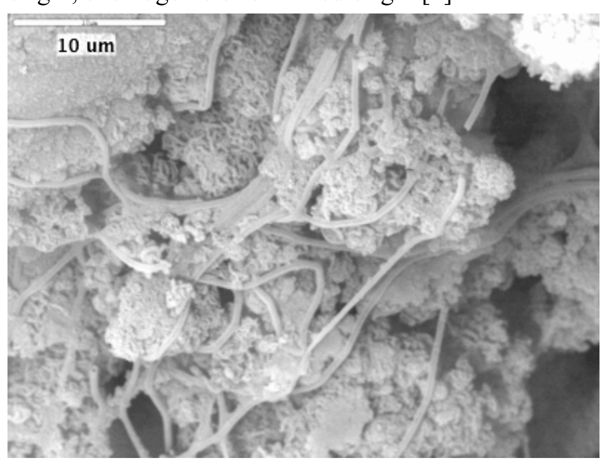

Fig. 1. Reticulated microbial filaments intermingled with chrysocolla from a Hawaiian lava cave.

References: [1] Cushing G.E. et al. (2015) *J. Geophys. Res. Planets*, 120, 1023-1043. [2] Boston et al., (2001) *Astrobio. J.*, 1, 25-55. [3] Northup et al. (2011) *Astrobio. J.*, 11, 1-18. [4] Barger et al. (2009) *GCA*, 73, 889-910. [5] Spilde et al. (2005) *Geomicro. J.*, 22, 99-116. [6] Self C.A. and Hill C.A. (2003) *J. Cave Karst Studies*, 65, 1230-151.